SRTM-Mission - Cross Comparison of X and C Band Data Properties

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INTRODUCTION†

In February 2000 the Shuttle Radar Topography Mission (SRTM) mapped large areas of the global landmass using two radar systems operating simultaneously in X and C band. The radar mapping instrument consisted of modified versions of the SIR-C C-band and X-band radars flown on the shuttle in 1994. Modifications included a 60 m retractable boom, with C-band and X-band receive-only antennas attached to the boom's end. High accuracy metrology systems were added to measure the shuttle position and attitude, and the position of the boom antennas. The dual apertures at each band form radar interferometers suitable for making high accuracy topographic maps of the Earth. The C-band data set is being processed by JPL for the archives of the US National Imaging and Mapping Agency (NIMA) and the National Aeronautics and Space Administration (NASA). The X band data set is processed and distributed at DLR Germany. This paper compares the specific properties of the X and C band data sets with respect to global coverage, height accuracy, sensor specific errors, product definition, product format and availability.

COVERAGE

The C-Band radar has an electronically steerable antenna and is therefore able to operate in ScanSAR mode with a 225 km swath. This provides complete coverage between +60° and –57° latitude, except for a few very small areas in the US. Most of the mappable area was imaged two or more times from ascending and descending vantage points. Combination of these data will reduce noise from each individual height map, and allow fill capability for those areas missed in a particular datatake. The X-Band radar system with its passive primary antenna is historically limited to a 50 km wide swath resulting in coverage holes of ca. 150 km x 150 km size at equatorial regions. X-band swaths are illustrated in Fig. 1.

Jumping ahead to Fig. 5, one can see the intrinsic difference in X-band and C-band coverage. With C-band operating in ScanSAR mode using two frequencies, four subswaths were generated to create a 225 km swath. The X-SAR 50 km swath lay between C-band beams 3 and 4. Where these datasets do overlap, there will be much new information regarding ground cover heights, as well as DEM cross-validation data.

All radar data acquired has been quality analyzed and no significant losses due to tape recorder failures have been found.

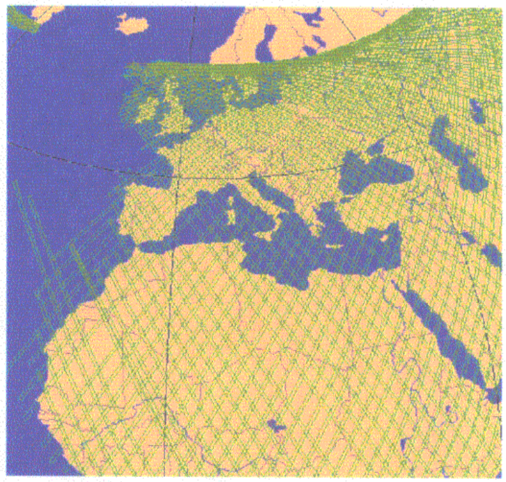

Fig.1: Coverage of X-Band data over Europe and Africa. The C-Band coverage map would be seamless below 60° latitude. In the area shown, three descending swaths were lost toward the end of the mission (wider gaps in X-band ground tracks above), but ascending coverage at C-band was complete.

HEIGHT ACCURACY

Since the calibration activities are still in progress at the time of writing, only preliminary results can be given here. More details on X-SAR are given in [Eineder, IGARSS-2001], and more on the C-band data are given in [Rosen et al. IGARSS-2001]. Height stability of the X- and C-band instruments over scales of several thousand kilometers has been analyzed for individual datatakes over ocean. C/X-SAR derived heights were compared with sea level height measured independently with satellite radar altimetry (ERS and TOPEX POSEIDON) to better than 10 cm for

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non-coastal waters. Using these results the Attitude Orbit Determination Avionics (AODA)-system has been calibrated. By optimizing the instrument alignment parameters as well as the processing algorithms, which digest the AODA raw data, errors on scales of 1000 km and less have been reduced by over an order of magnitude since the begin of the calibration phase. The current status for the X-band and C-band is shown in Fig. 2; remaining errors are on the order of +/-10 m.

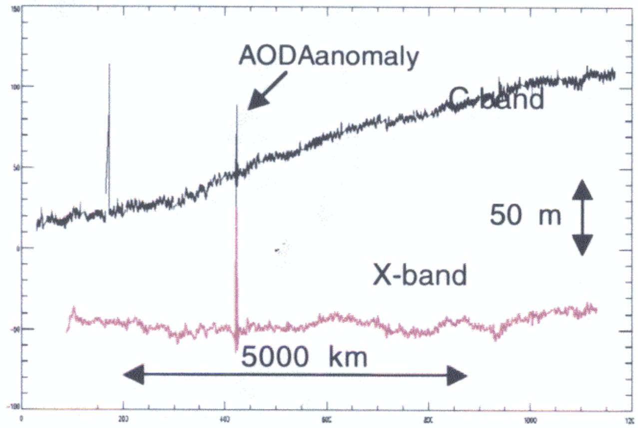

Fig.2 X-band and C-band height relative to true sea level for the 8000 km long datatake 146.190 over the southern Pacific. The AODA data anomaly has recently been corrected. The residual gentle 0.0007° slope of the C-band data may be due to orbital variations in C-radar phase differences in the interferometer.

Height trends on scales of more than a few thousand km are expected due to biases and slow drifts of instrument constants during the mission. These will be removed during the final calibration phase where all ocean-land crossings will be co-analyzed.

Fig. 3 shows a DEM over Gujarat, India from X-SAR data. A differential X-SAR DEM between ascending and descending passes over this area showed a standard deviation of 3.3 meters over land area with moderate to flat terrain.

Again jumping to Fig. 5, the C-band version of the India DEM can be seen. The expected height noise of intrinsic unfiltered C-band mosaicked height maps was on the order of 5–10 m. To reduce the random noise in relatively flat areas while preserving structure when slope become large, a new adaptive regridding scheme is applied to the data, whereby the flat areas are filtered heavily to reduce noise, while the sloped areas are lightly filtered [Hensley, 2000]. After this adaptive regridding, the final mosaicked height errors in the flat regions with reasonably good signal level are between 1-2 m RMS. The X-band data are typically not filtered as heavily, so the intrinsic data resolutions of the two data sets are different. From a topographic structure viewpoint, however, the X and C band data should contain very similar information. The X-band and C-band data are therefore of quite similar quality and can be productively compared in the regions of overlap.

Fig. 3: Color coded X-SAR DEM over Gujarat, India

SENSOR SPECIFIC DATA PROPERTIES

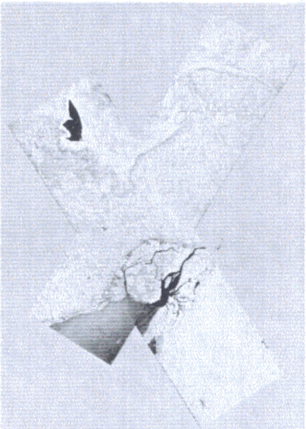

Fig. 4: Grey-scale X-SAR Coherence over Gujarat, India. Black is a coherence of 0, white 1. Note coherence is quite good everywhere except very smooth water. Similarly, the C-band coherence is upward of 0.98 over most flat land surfaces.

Fig. 4 shows the X-SAR coherence map over Gujarat. The coherence depends essentially on the image brightness and influences the height error, which is less than 4 meters standard deviation for the expected range of coherence. X-SAR operates at a relatively flat incidence angle of 54 degree and is therefore more sensitive to flat or dark surfaces than C-band at steeper incidence angles. This flat incidence angle may also cause radar shadow in very steep terrain.

The C-band coherence is very high, usually greater than 0.98 in flat moderately bright regions.

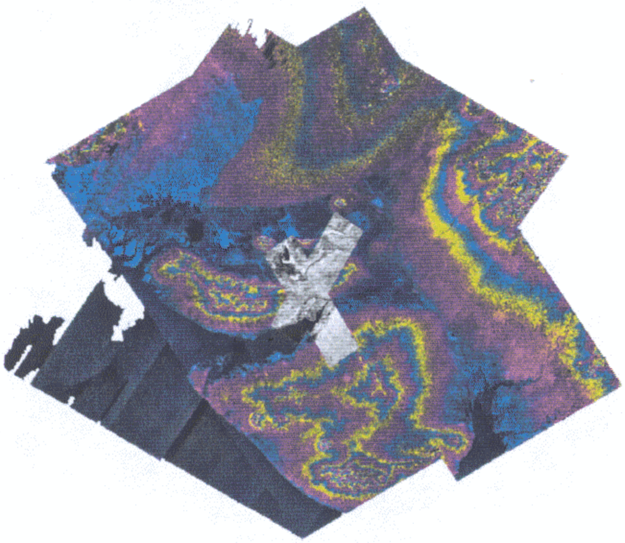

Fig. 5: Coverage of the C-band sensor operating in ScanSAR mode in the region surrounding Gujarat, India. This mosaic comprises two ascending and two descending swaths covering roughly 400 km x 400 km. The X-SAR data of Fig. 3 is shown for reference in grayscale. Color depicts height in 100 m contours, while brightness indicates radar backscatter intensity. This preliminary product has less than 1 dB of radiometric error across range, but some banding is still visible over land. Banding over water is expected because of the range of incidence angles. Fully processed X-SAR data would continue along the tracks shown north and south, and in parallel spaced by about 200 km from tracks shown.

Since X-SAR operates in strip map mode as during the scientific SIR-C/X-SAR missions in 1994, compatible standard image products will be available at DLR.

PRODUCT FORMAT AND DEFINITION

X-SAR product properties are described in [A. Roth, IGARSS]. For C-band, there will be several kinds of data products available to a variety of user communities. NIMA will accept data that conforms as closely as possible to their DTED-2 specification. These data have the following characteristics: 1° latitude by 1° longitude cells of height data relative to the geoid, height error data and radar brightness data corregistered to the height data, posted at 1 (2 at high latitude) arcsecond spacing. NIMA will post-process these data to finish conversion to the DTED-2 standard. This primarily involves setting the height of identified water bodies to the mean shoreline value.

In addition to the NIMA data, NASA will produce and archive various data sets for the science community. These data will likely be similar in content and format to the NIMA data, but may lack water body editing, and other meta-data fields.

PRODUCT AVAILABILITY

All X-SAR data is property of the German Aerospace Center DLR and Italian Space Agency ASI. Therefore all X-SAR data except data over Italy are processed, archived and distributed at full resolution by DLR. Apart from selected sensitive areas no restrictions will apply. C-band raw data are owned by NIMA. One arcsecond data over the US will be freely available, as will 3 arcsecond data over the world. NIMA is presently restricting access to 1 arcsecond data outside the US, but investigators can make special requests through NASA.

HYPERLINKS FOR ADDITIONAL INFORMATION

For a complete description of the C-band component of the SRTM Mission, visit http://www.jpl.nasa.gov/srtm. For a complete description of the X-band component of the SRTM Mission, visit http://www.dfd.dlr.de/srtm. The coverage of the acquired X-band data can be accessed at http://www.eoweb.dlr.de.

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